Spill for Juvenile Fish Passage at Corps Projects in The Columbia River Basin

Author: Scott W. Boyd
Hydraulic Engineer, Reservoir Control Center
US Army Corps of Engineers
Northwestern Division
North Pacific Water Management Division
Attention: CENWD-CM-WR-N
P.O. Box 2870
Portland, OR 97208-2870
Phone: 503-808-3943
Email: scott.w.boyd@usace.army.mil

Abstract

The 1995, 1998 Supplemental and the 2000 National Marine Fisheries Service (NMFS) Biological Opinions all called for spill at the eight mainstem projects operated by the U.S. Army Corps of Engineers (Corps) on the Lower Columbia and Snake Rivers to protect multiple salmon and steelhead species listed as endangered or threatened under the Endangered Species Act (ESA). Spill for juvenile fish passage has been provided at Corps projects since 1977. The purpose of this spill is to increase project passage survival and reduce delays for juvenile salmon and steelhead migrating downstream. Spill for juvenile fish passage occurs during the juvenile fish passage season (April – August). The spill at each of the projects varies according to the conditions at each project. The amount spilled is either a percentage of total flow or a fixed amount. Spill may be around the clock or for a set time period. Spill may not exceed an amount that will cause greater than 120% total dissolved gas concentration below the projects. Other limitations on the amount spilled are the need to maintain minimum generation requirements and limiting the amount of adult salmon fallback.

This paper describes the spill programs specified by each of the Biological Opinions and how spill varies at each of the eight projects. The paper will also describe how the spill program is managed on a day-to-day basis including how the maximum spill amounts are determined.

Introduction

There are many actions implemented by the Corps of Engineers, which aid in the recovery of Pacific Northwest salmon and steelhead populations. One major operation is the spilling of water at eight Corps of Engineers dams on the Columbia and Snake rivers. In my paper I will look at the current spill program and also at some of the spill programs in the recent past. I will explain why the Corps spills water and how the current spill is managed. Also, I will describe some of the limits to spill at

the projects and some developments that have the potential to change the spill program in the future.

Effects of Projects on Salmon

Corps' dams and reservoirs cause several problems for juvenile salmon and steelhead. In the rest of the paper I will use the term salmon to refer to all the ESA listed species. There are problems caused by the effects of the reservoirs, which include slower travel time, increased predation and high water temperature. There is also the problem of getting the juvenile salmon that are traveling downstream to the ocean past the dams. Spill at the projects is a method to help the juvenile salmon get past the dams with the least harm to them.

Juvenile Fish Passage

A juvenile salmon can face the prospect of migrating through up to 8 Corps projects on its way to the ocean. Each of these projects has the potential of causing injury or mortality for some of juvenile fish going past it. The cumulative effects of even a small percentage loss at each project can add up to a large loss. For example if 5% of the fish passing each project were killed, 33% of the total juveniles that had to pass the 8 projects would be killed. So the Corps' goal is to reduce fish injury and mortality to the extent feasible and provide safe, efficient passage for fish.

There are three major routes that a juvenile salmon takes when passing a dam. The first route is to pass the project by going over the spillway. In most cases this is considered the route with the least harm to juvenile fish. The second route is to enter the intake of a turbine but be diverted into the juvenile bypass system. The third route is to enter the turbine intake and pass through the turbine. This route is the least desirable route for juvenile fish passage. Not only are some fish injured by the turbine (direct injury) the disorientation caused by the passage (indirect injury) can make them easy prey for predators downstream of the dam as they exit. The spill program at Corps projects is designed to get more juvenile fish to use the first route.

Transportation

Juvenile salmon that take the second route, the bypass system, can be collected for transportation. There are four projects on the Columbia and Snake Rivers that can collect fish for transportation. They are Lower Granite, Little Goose, Lower Monumental and McNary Dams. See Figure 1. These projects are referred to as collector projects. Transported juvenile salmon get a ride, either on barge or in a truck downstream past all the remaining projects and are released below Bonneville Dam (the furthest downstream project). The benefit to transported juvenile salmon is that they arrive at the ocean faster and avoid some of the mortality associated with traveling in the reservoirs and mortality passing the projects.

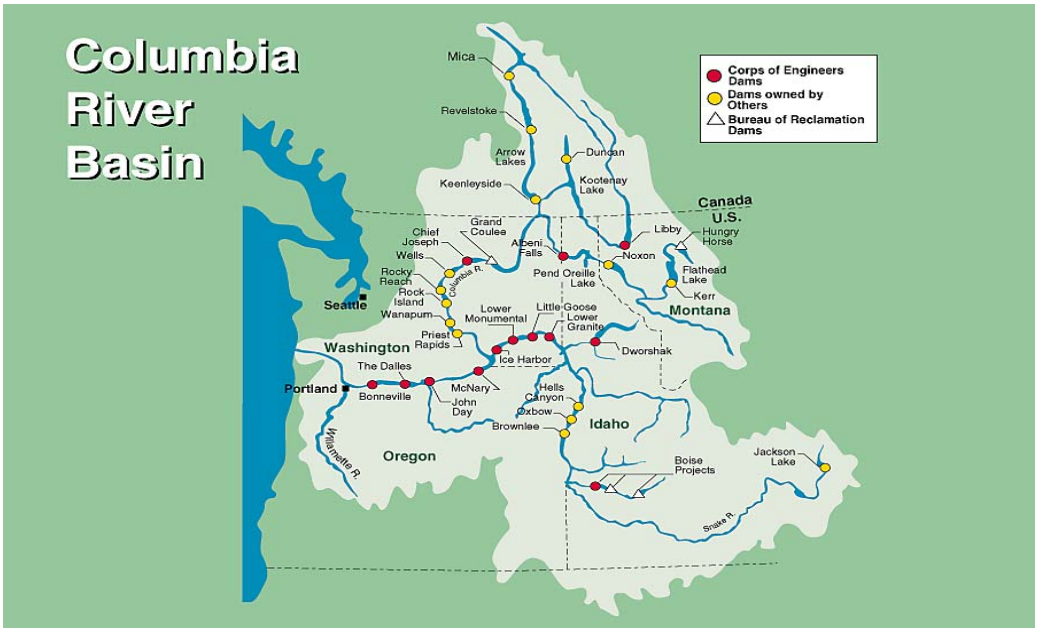

Figure 1. Map of Columbia River Basin

Limits to spill

It would appear that the more water that is spilled at a dam the better it would for juvenile fish passage. However, there are several constraints, which limit the amount of spill that can be provided at a dam. The first is that water flowing over a spillway causes gases to be entrained in the water. These entrained gases can cause injury to adult and juvenile salmon as well as other fish species. This injury is caused by the expansion of gas in the fish's cell like what occurs when a diver gets the bends. The amount of entrained gases is measured by comparing the gas pressure in the water with the barometric pressure. This measurement is called the total dissolved gas (TDG). At the current time the Corps limits TDG to a level of 120% directly below the project and to a level of 115% at the next project downstream. The state standard for TDG is 110% in Oregon and Washington but those states have temporarily waived the standard to benefit juvenile salmon passage at dams. The 120% TDG limit is also part of the NMFS BiOp.

A second problem that excess spill can cause is injury to juvenile fish. Similar to passage through a turbine, going over a spillway can cause both direct and indirect injury to fish. Research has shown that higher levels of spill can cause higher total project mortality to the juvenile fish passing a project as compared to a lower level of spill even if a higher proportion of juvenile fish have to pass through the bypass system or the turbine.

A third problem that excess spill can cause is adult salmon fallback. Fallback occurs when an adult salmon that has already passed a project going upstream is swept back in the spill over the spillway, so that it must pass the project again. Higher amounts of spill have been shown to increase the rate of fallback at certain projects.

Another factor that limits the amount of spill is the minimum generation requirements at the projects. Because of improvements that have been made over the years at the projects, mainly flow deflectors; it is possible at some projects to spill almost the entire flow of the river at certain times. Flow deflectors are devices that deflect spill so it does not plunge down into the water but is deflected to more along the surface of the water, reducing TDG. The Bonneville Power Administration (BPA) had the need to have minimum generation level at the projects so that power system reliability can be maintained. This minimum flow level, and the resultant power generation, is 30 Kcfs at Bonneville, 50 kcfs at The Dalles, John Day and McNary. These minimum generation limits are in place year round. The Snake River projects also have a minimum generation levels of around 11 kcfs, which can be used if needed, but is often not called upon.

1995 BiOp Spill

Spill has been going on since 1977 at Corps projects. The spill program prior to the current spill program was defined in the 1995 National Marine Fisheries Service Biological Opinion (BiOp).

Juvenile Fish Passage Goal

One of the 1995 NMFS BiOp actions recommended the Corps of Engineers achieve 80% of the juvenile fish passing by each project to pass the project by the first two methods, either by spill or the bypass system, other than through the turbines. This number is called the fish passage efficiency (FPE) and refers to the proportion of fish passage through non-turbine passage routes. The Corps was to spill enough water to achieve this percentage. It was realized in the BiOp that this was not possible at all projects.

How FPE is computed

FPE is determined in the following manner. First it is assumed the juvenile fish are equally proportioned in the river flow. For example, if half of the water going downstream were spilled then half the juvenile fish would go over the spillway. The other part of the FPE is the percentage of the juvenile fish that entered the turbine intake that are guided into the juvenile fish bypass system. This percentage is called the fish guidance efficiency (FGE). The FGE varies at each of the projects and varies by the species of salmon. The FGE at each project and for each species are determined by research. The formula to determine FPE is:

FPE = (spill percentage) + ((1 – spill percentage) * FGE))

As an example, assume a total flow of 150 kcfs with a spill of 80 kcfs. This would give a spill percentage of 53%. If the FGE was 40% then FPE is 72%

Using algebraic manipulation a determination can be made of the spill percentage needed to get to a desired FPE as:

Desired spill percentage = (FPE – FGE) / (1- FGE)

For example, if total flow is 150 kcfs and FGE is 40%, an FPE of 80% would require spilling 67% of the total flow, or 100 kcfs.

Spill Amounts

Based on FGEs determined by research, the following spill percentages would provide 80% FPE

Table 1. Spill percentages 1995 BiOp

	Spill % Spring	Spill % Summer	Spill Hours
Bonneville	*	*	24 hours
The Dalles	64	64	24 hours
John Day	33	86	1800 – 0600
McNary	50	N/A	1800 – 0600
Ice Harbor	27	70	24 hours
Lower Monumental	81	N/A	1800 – 0600
Little Goose	80	N/A	1800 – 0600
Lower Granite	80	N/A	1800 – 0600

* At Bonneville spill was limited to 75 kcfs due to adult fallback during daytime spill and to TDG limit during night time

The planning dates to operate projects to spill on the Columbia River projects (Bonneville, John Day, The Dalles, and McNary) were April 20th to June 30th for spring spill and from July 1st to August 31st for summer spill. On the Snake River projects (Ice Harbor, Lower Monumental, Lower Granite) the planning dates were April 10th to June 20th for spring spill and from June 21st to August 31st for summer spill. The significance of the spring and summer spill period is that at projects where juvenile fish are collected (McNary, Lower Monumental, Little Goose, Lower Granite) is considered better, by NMFS, to transport the maximum amount of juvenile fish due to poor in river conditions in the summer.

1998 / 2002 BiOp Spill

The current spill program was begun under the 1998 NMFS supplemental BiOp. The spill program was changed from spilling enough water to reach 80% FPE. To spilling a percentage of total project outflow or spilling to the waived TDG limit.

Why Change

This change in the spill program was made because some of the limits to spill given above it not allow for the 80% FPE to be reached at some at some of the projects. Mainly the 120% gas cap limited spill at some projects and some low FGE numbers at some projects meant that the 80% was not reached. NMFS decided in the 1998 supplemental BiOp to recommend the maximum spill amount at each project that would benefit juvenile fish projects.

New spill approach

The new approach to the amount to spill at each project was to spill a certain percentage of the total outflow, or to spill to the 120% TDG limit. Spill at the projects is either for 24 hours a day or only during nighttime hours (normally 1800 – 0600). Juvenile fish move during the night so spill is more beneficial at some projects at nighttime.

Current Spill Program

In the paragraphs below I describe the 2003 spill program and how it is managed as an example of the current program.

Timing

Spill occurs when juvenile fish begin to appear in the river, the planning dates for the Columbia River projects (Bonneville, John Day, The Dalles, and McNary) are from April 10th to June 30th for spring spill and from July 1st to August 31st for summer spill. For the Snake River projects (Ice Harbor, Lower Monumental, Lower Granite) the planning dates are from April 3rd to June 20th for spring spill and from June 21st to August 31st for summer spill. The significance of the spring and summer spill period is that at projects where juvenile fish are collected (McNary, Lower Monumental, Little Goose, Lower Granite) is considered better, by NMFS, to transport the maximum amount of juvenile fish due to poor in river conditions in the summer.

Current Spill Program

Below is a short description of the current spill program at each of the eight Corps projects. In all cases where a percentage of the total flow is to be spilled the spill is not to exceed the 120/115% TDG limits.

Bonneville

Spill up to the 120/115% TDG limits in the evenings. Spill is limited during the daytime to 75 kcfs, which is lower than the TDG limit, due to adult fallback problems. Over the last several years daytime flows has been switched between the fallback limit and the 120% TDG limit to determine the effect on adult fallback and juvenile survival.

The Dalles

Spill 40% of the total flow 24 hours a day.

John Day

Spill 60% of the total flow at nighttime. Over the last several years, different percentages of nighttime spill and some daytime spill (percentage of total flow) has been tested to determine the best mix of day and nighttime spill.

McNary

Spill up to the 120% TDG limit at night.

Ice Harbor

Spill up to the 120% TDG limit at night. Spill limited to 45 kcfs in the daytime, which is less than the TDG limit, due to adult fallback problems.

Lower Monumental

A new spill program was started this year. Spill 50% of total flow if the total flow is below 75 kcfs or greater than 100 kcfs. Spill 45% of total flow if the total outflow is between 75 and 100 kcfs. Spill is for 24 hours a day. The differing spill percentages are to improve exit conditions at the tailrace and are based on model studies at ERDC-Vicksburg.

Little Goose

Spill up to the 120% TDG limit at nighttime.

Lower Granite

Spill up to the 120% TDG limit at nighttime. Last year tests began on an RSW (removable spillway weir) at Lower Granite see discussion below.

1 % unit operating limits

Another limitation on the spill program is the requirement to operate generation units at the project within set limits. The NMFS BiOp requires that all generation units at the eight projects operate within 1% of their peak efficiency range. This requirement gives a minimum and a maximum flow at which the project can operate. For example, if a project has a 120% TDG limit of 45 kcfs and its generation units can operate in a range of 10 to 15 kcfs and still stay within the 1% efficiency limits, and the total outflow from the project is 50 kcfs, the project cannot spill 45 kcfs because the remaining 5 kcfs is not enough flow to meet project minimum generation requirements. Therefore the project would have to spill 40 kcfs and generate with 10 kcfs. Most of the projects have limited storage and. the ability to control outflow.

Minimum spill levels

Another item that can limit the amount of spill is that low levels of spill may cause such poor exit conditions from the tailrace that a minimum spill level of either a percentage of total outflow that can be spilled or a specified minimum flow limit is set. Poor tailrace conditions can cause higher levels of predation, therefore a preferred passage route is to have juvenile fish go through the bypass system or through the turbines. At other projects, when low river outflow causes the spill levels to get so low that poor exit conditions occur the spill may be changed to allow spill at higher level, than would otherwise be possible, for a shorter period of time.

Day-to-Day operations

The biggest hurdle to daily operation is the 120% TDG limit for each project. Because the 120% TDG limit is above the current state standard of 110% TDG the Corps of Engineers has to apply for a waiver to exceed the standard. The waivers set the TDG limit. The Water Quality Team of the Reservoir Control Center looks at data each day to compare the total spill at dam to the amount of TDG being produced at that dam and the forebay of the dam downstream. If the TDG is over the waived standard, the flow limit is reduced. If the data demonstrates the TDG is below the waived limit, the spill amount may be raised. Some limits change every day. Some of the fisheries managers feel that the Corps of Engineers does not get close enough to the 120% TDG limit, yet Corps policy is to approach the waived limit as closely as possible without exceeding the 120% TDG.

In addition to monitoring the TDG levels at the projects, the Fish Team of the Reservoir Control Center issues the instructions to the projects and BPA on how to implement the spill program. The Fish Team also monitors the spill to see if the correct amount of spill was provided.

Spill in low flow years

In low flow years, when the projected flow at Lower Granite during the period April 3 through June 20 is expected to be lower than 85 kcfs, no spill is to occur at the Snake River collector projects. If no spill occurs juvenile fish transportation can be maximized due to poor in river conditions.

How much is spilled

Below is a table that show how much water was spilled for juvenile fish passage in 2002 and how much generation was lost due to this spill. Note there was no spill at Lower Monumental is 2002 because of construction work going on in the tailrace.

Table 2. Water Spilled in 2002

Project	Volume spilled MAF	% Of total flow spilled	Mega watt hours lost
Bonneville	30.80	45%	1.6E+06
The Dalles	24.12	36%	1.7E+06
John Day	17.74	26%	1.8E+06
McNary	10.50	28%	6.5E+05
Ice Harbor	13.41	71%	1.2E+06
Little Goose	3.77	30%	3.2E+05
Lower Granite	3.10	24%	2.8E+05

Spill Patterns

Not only is the quantity of water being spilled important, but also where across the length of the spillway is important. Each project has a spill pattern, which sets how much flow is released from each bay at each spill level. These spill patterns are designed to provide good exit conditions for juveniles going downstream and good conditions for adults going upstream. Spill patterns are shaped according to the dominant biological need at the project. It can be crowned, shaped to one side or the other, or can be flat. Part of a typical spill pattern is shown below. See Figure 2.

Future

The Corps of Engineers along with other fishery agencies are continuing to work on improvements to the spill program. This year the Corps is testing a Removable Spillway Weir that will pass more juvenile fish while spilling less water. This will benefit both the fish and power generation, more juvenile fish will get safely by the project using less spill, thereby providing more power generation. Also we continue to work on methods to reduce the amount of TDG produced.

Spill Bay								Total Stops	Total Spill Kcfs
1	2	3	4	5	6	7	8		
0	1						0	1	1.8
0	1	1					0	2	3.6
0	1	1	1				0	3	5.4
0	1	1	1	1			0	4	7.2
0	1	1	1	1	1		0	5	9.0
0	1	1	1	1	1	1	0	6	10.8
0	2	1	1	1	1	1	0	7	12.6
0	2	2	1	1	1	1	0	8	14.4
0	2	2	2	1	1	1	0	9	16.2
0	2	2	2	2	1	1	0	10	18.0
0	2	2	2	2	2	1	0	11	19.8
0	2	2	2	2	2	2	0	12	21.6
0	3	2	2	2	2	2	0	13	23.4

Figure 2 Typical Spill Pattern.

A removable spillway weir (RSW) is a weir that is placed in front of an open spillbay that can be lowered if a large amount of spill is needed in case of a high river flow. The advantage of the RSW is that the flow is drawn from the surface where juvenile salmon like to swim, rather than using a spillbay with tainter gates where the fish have to dive down to the ogee to pass. The first RSW was tested last year at Lower Granite and it showed very good results in passing more juvenile fish per volume of spill than the traditional spillbay. Continued testing will occur this year. The Corps hopes to install more of these in the future.

References

NMFS (National Marine Fisheries Service). 1995. *Biological opinion – reinitiation of consultation on 1994-1998 operation of the Federal Columbia River Power System and juvenile transportation program in 1995 and future years.* NMFS, Hydro Program, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1998. *Supplemental biological opinion – operation of the Federal Columbia River Power System including the smolt monitoring program and the juvenile fish transportation program: a supplement to the biological opinion signed on March 2, 1995, for the same projects.* NMFS, Hydro Program, Portland, Oregon.

NMFS (National Marine Fisheries Service). (2002), *Biological opinion – Reinitiation of Consultation on Operation of the Federal Columbia River Power System, Including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin*. NMFS, Hydro Program, Portland, Oregon.